

Update on JAXA studies and way forward in Japan

**Hideyo Kunieda
Nagoya University
and
IXO Working Group**

IXO Science Meeting @Paris, April 27-29, 2010

Strategy of Japanese X-ray groups

ASCA --> Suzaku --> Astro-H --> IXO

Science

High resolution Spectroscopy
Hard X-ray Astronomy

Technology

Hard X-ray telescopes
Hard X-ray Imagers
Extensible Optical Bench
Cryogenics

Strategy of Japanese X-ray groups

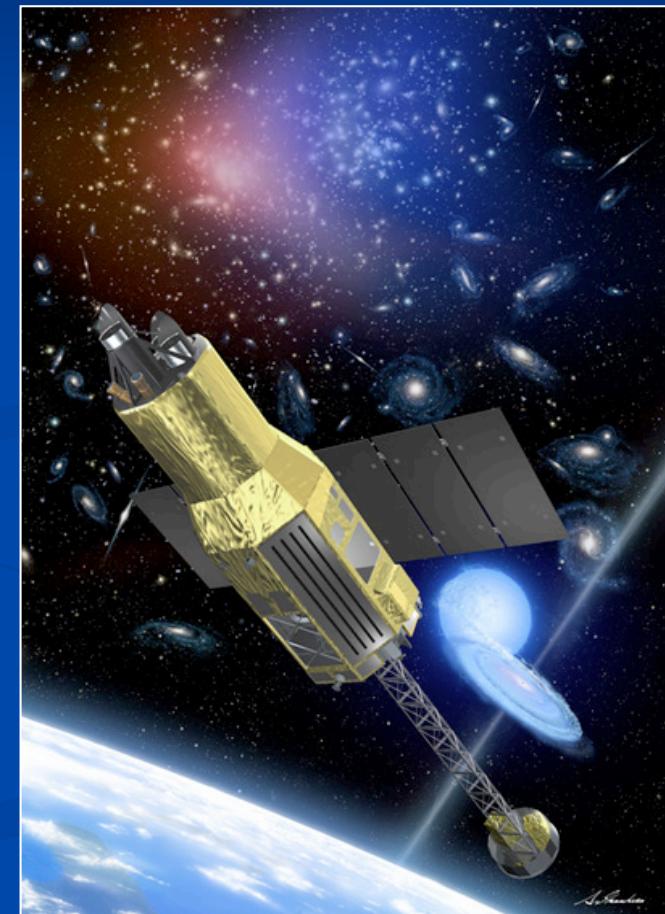


Science

Astro-H

High resolution Spectroscopy
Hard X-ray Astronomy

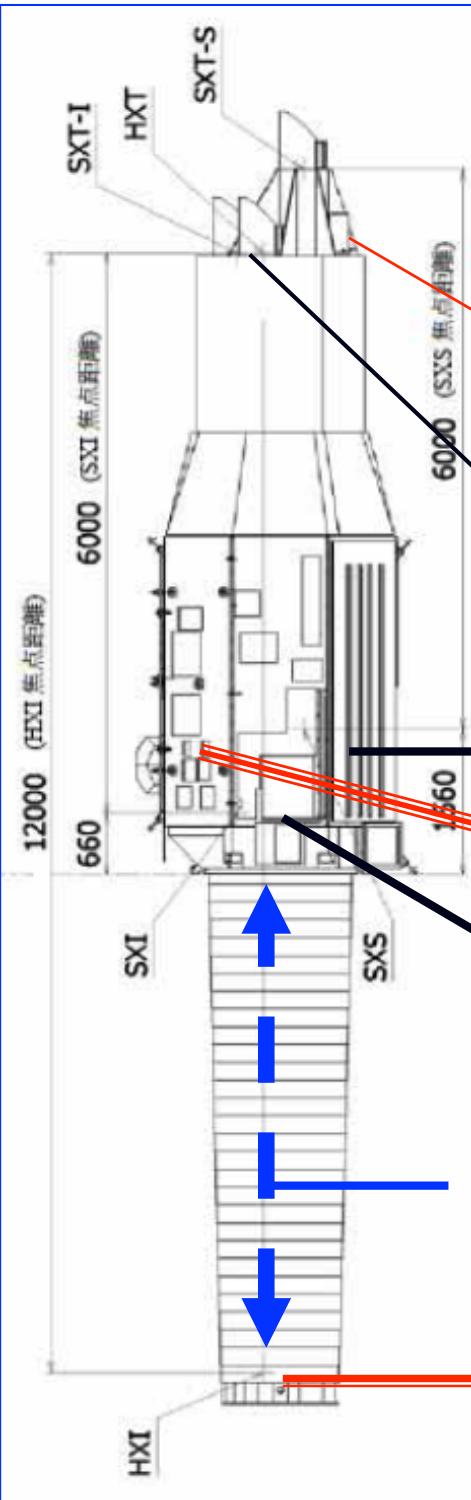
Orbit 550km, Incl. 31°
Total weight 2.4t
Length 14m
Power 3150W (BOL)
Launcher H-IIa(dual)
To be launched in **2014**



System PDR on May 13-14, 2010



Astro-H



Hard X-ray Telescopes
(2HXT)

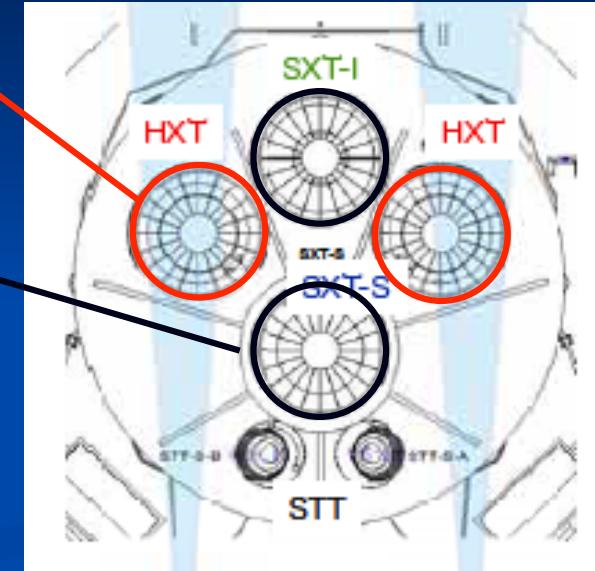
Soft X-ray Telescopes
(2SXT)

Soft X-ray imager(XIS)
X-ray Spectrometer(XRS)

Soft Gamma-ray
Detector(2SGD)

Extensible Optical
Bench (EOB)

Hard X-ray
Imagers(2HXI)

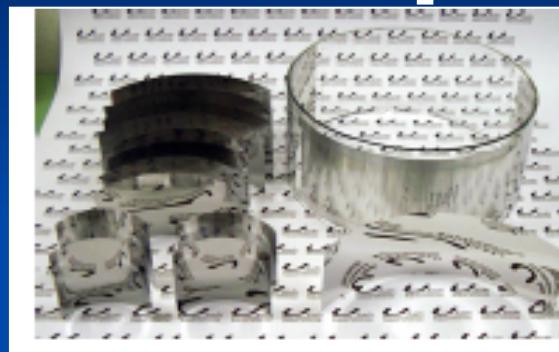


Top View



Astro-H

Hard X-ray Telescopes(2HXT) :: Soft X-ray telescopes(2SXT)



Replica mirrors

NASA

Nagoya, Ehime, ISAS

High throughput
Thin foil mirrors(213)

+

Multilayer Supermirrors
for Hard X-ray optics

45 cm Φ , 12m F.L., <1.7' HPD

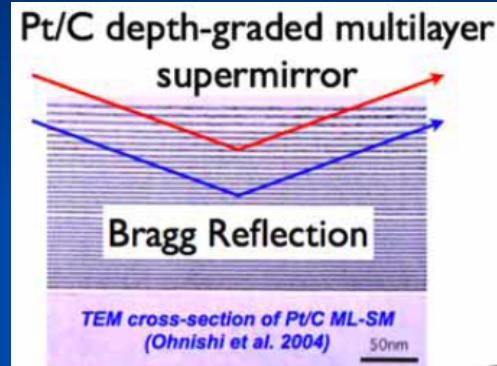
Substrate: 0.2t Al
Epoxy 25 micron
Glass mandrel(Schott)
Au, Pt, Pt/C coating

45 cm Φ , 5.6m F. L., ~ 1' HPD



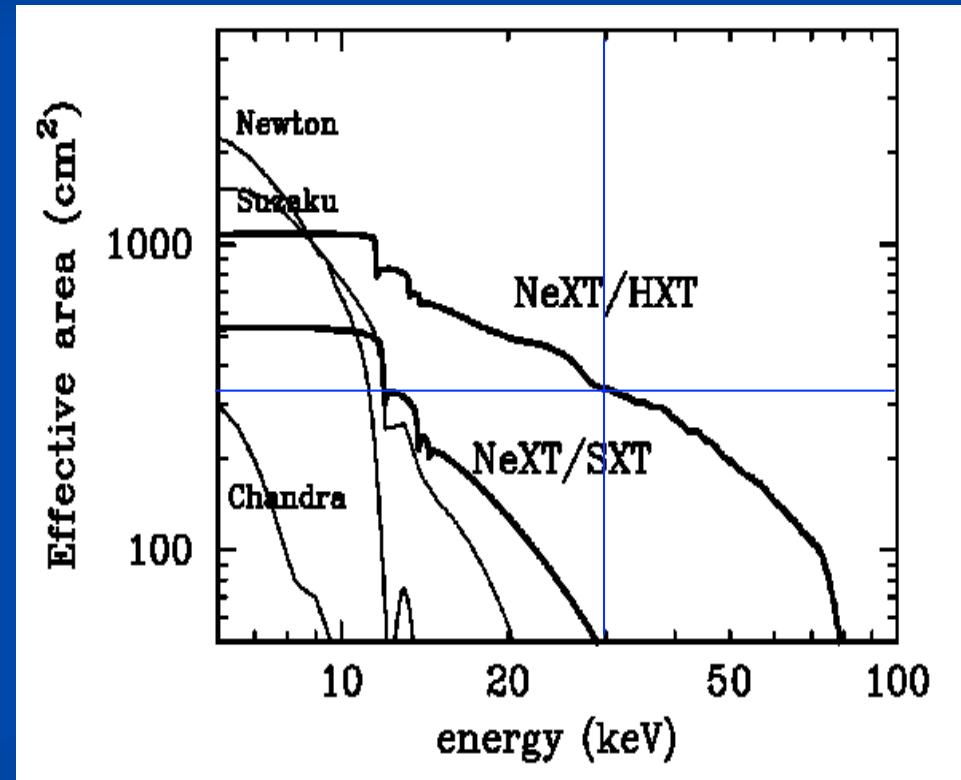
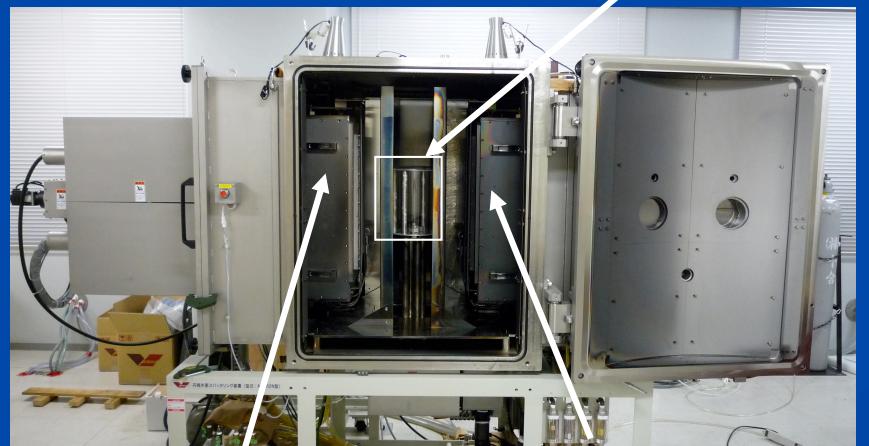
Astro-H

Multilayer Supermirrors



$\theta = 0.07 - 0.27^\circ$
Pt/C 28-138 layer pairs
 $d = 2.5 - 10 \text{ nm}$

Sputtering Chamber
@ Nagoya University



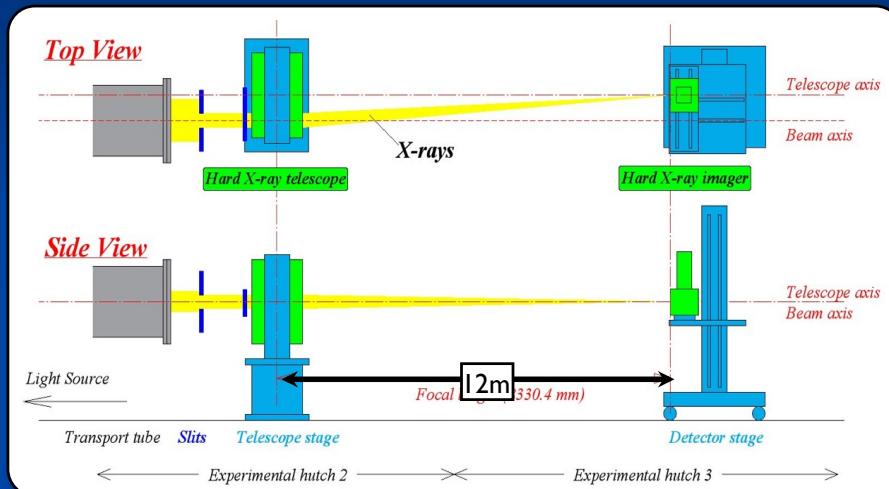
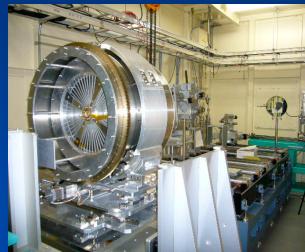
$S(30 \text{ keV}) > 300 \text{ cm}^2$



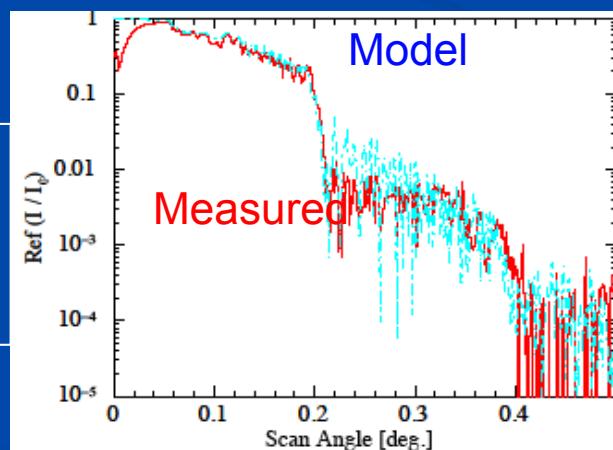
Astro-H

Hard X-ray Calibration at SOR (SPring -8)

SPring-8
Strong, stable
Monochromatic
Parallel beam
8 - 200 keV



Pt/C 79 pairs ($d=32\text{-}118\text{\AA}$)
@ 0.15 degrees
 $\sigma_{DW} = 3.8 \text{ \AA}$ @ 60 keV



Astro-H HXT EPR
Willingale(Chair)
O'dell, Pareschi
Petre visited SPring-8
on Feb. 20-21, 2010



Astro-H

Mass production plan

Rehearsal(Apr. 5-9, 2010)

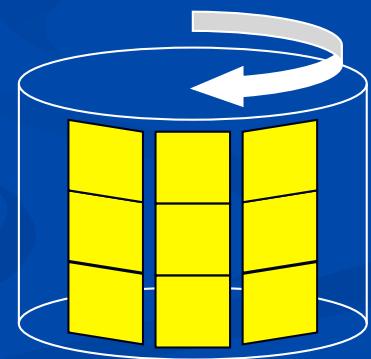
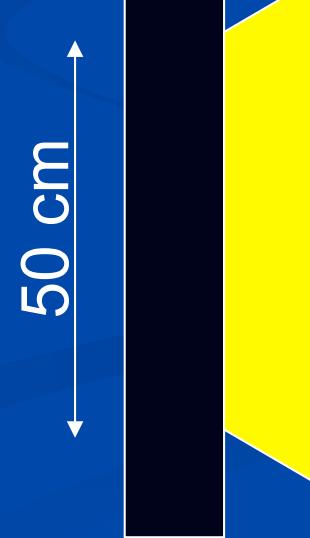
12 foils/day x 250 days $\frac{2}{3} \frac{2}{3} = 1300$ foils/y ~ 1 telescope
Two telescope (2010-2012)
Calibration and integration in 2013

Mass production line @ Nagoya



3 Sputtering Chambers

Sputter Target



Si wafer



Astro-H

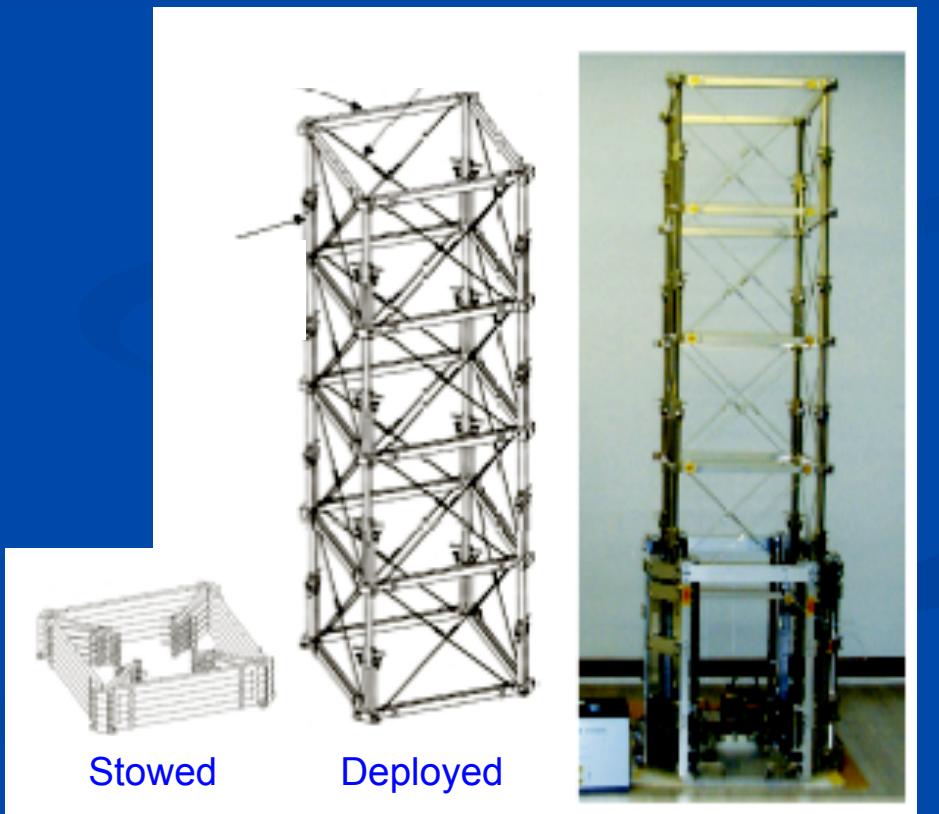
Extensible Optical bench(EOB)

ASCA, Suzaku, HALCA
60cm, 140cm, 400cm

CPRP (Stiff, light, small ct)

Deploy detector module
with 2 HXI + radiator

Engineering Model



Similar configuration of IXO



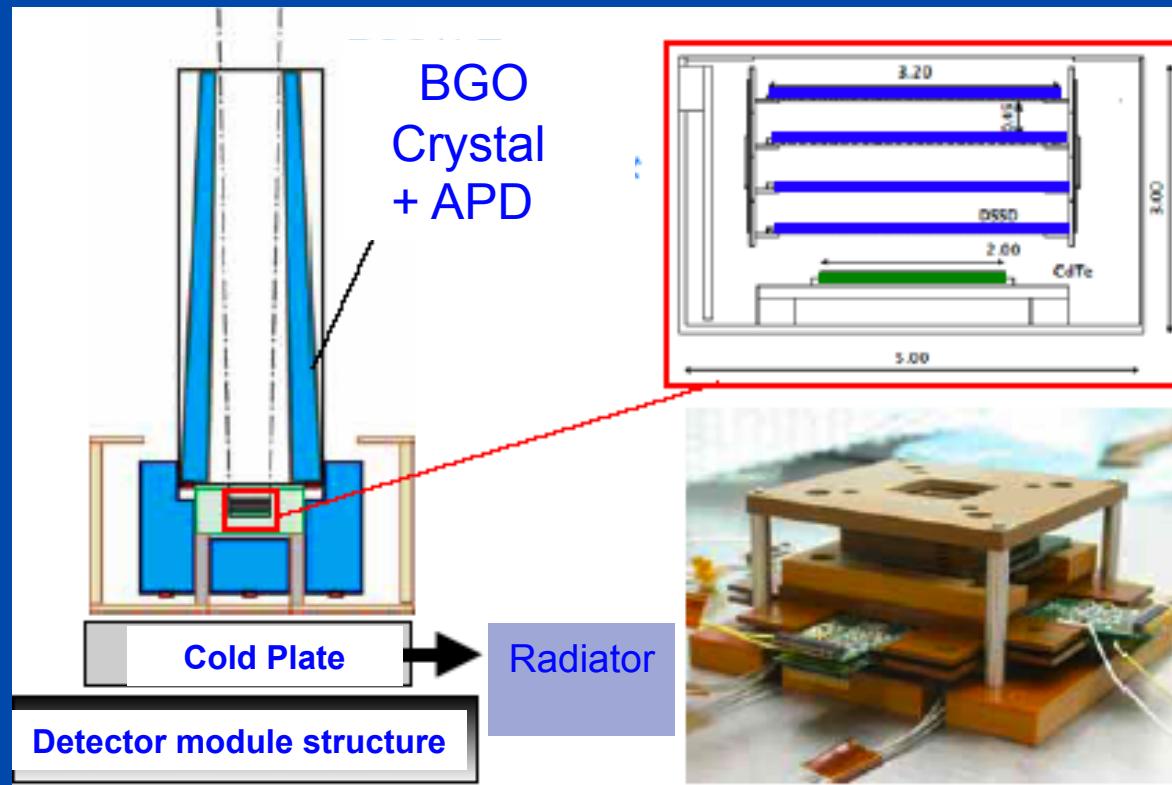
Astro-H

Hard X-ray Imaging Detector (HXI)

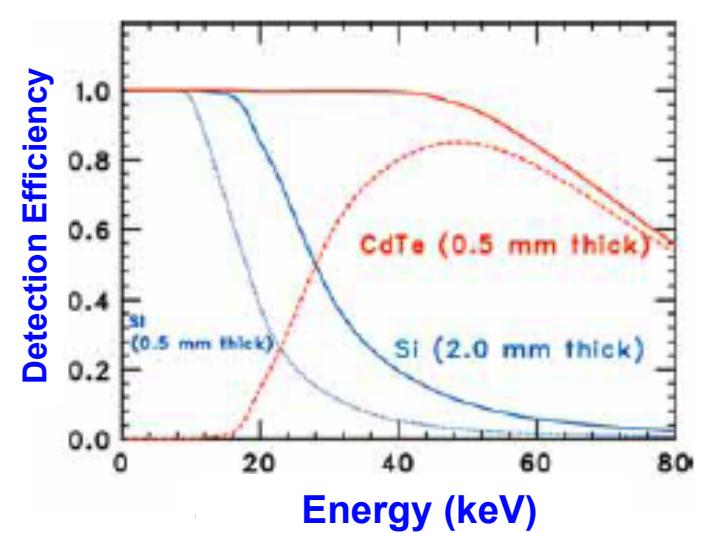
4 layer Si strip detector + CdTe imager(-30°C)

Well type guard detector(BGO+APD)

~ IXO WFI



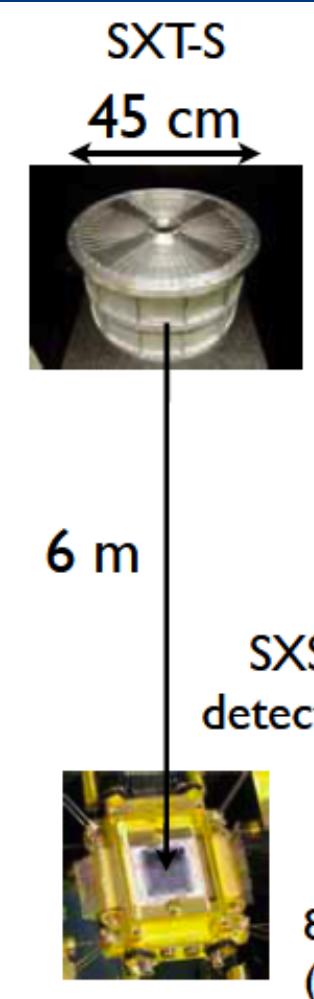
4 layers of Si imager
+ CdTe Imager





Astro-H

Soft X-ray Spectrometer(SXS)



The diagram shows the SXS detector assembly. On the left, there is a photograph of the detector with a scale bar of 45 cm. A vertical line extends from this photograph down to another photograph of the detector's internal circuit board, which is labeled "SXS detector". To the left of the top photograph, the text "SXT-S" is written vertically, and to the left of the bottom photograph, the text "6 m" is written vertically, indicating the distance between the two components.

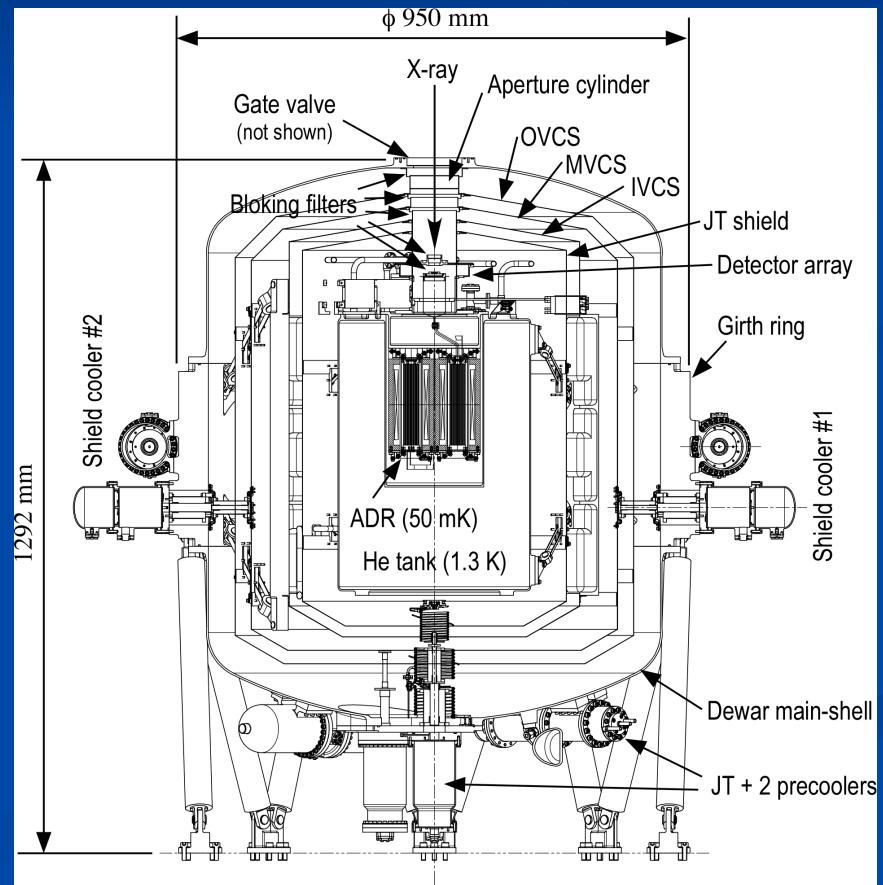
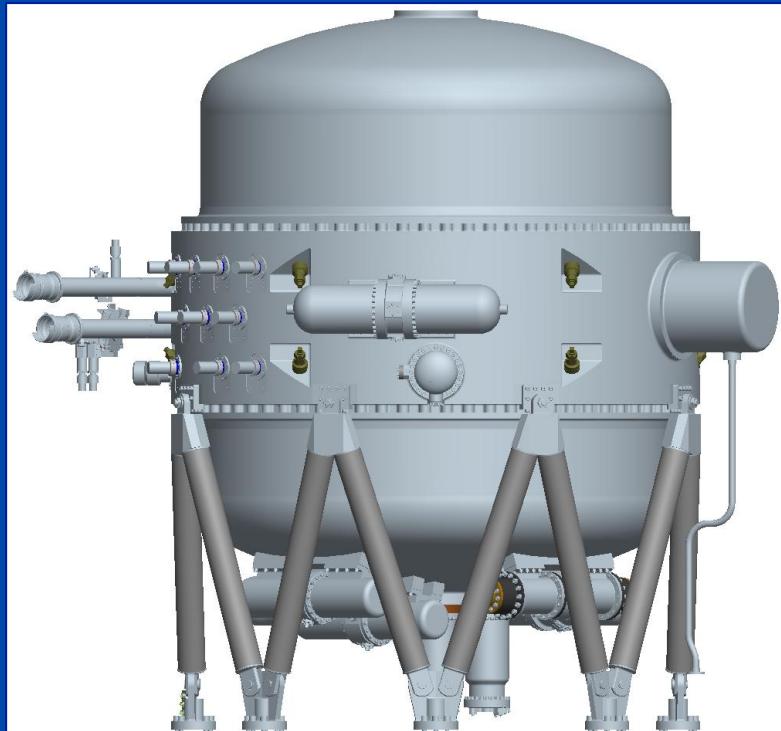
	Requirement	Goal
pixel size	> 800μm	
Array format	6 x 6 (32 pixel readout)	8 x 8 (64 pixel readout)
Energy range	0.3 - 10 keV	
Energy Resolution	7 eV	4 eV

810μm x 810μm pixel, 6 x 6 array
(8 x 8 array as option) 50 mK



Astro-H

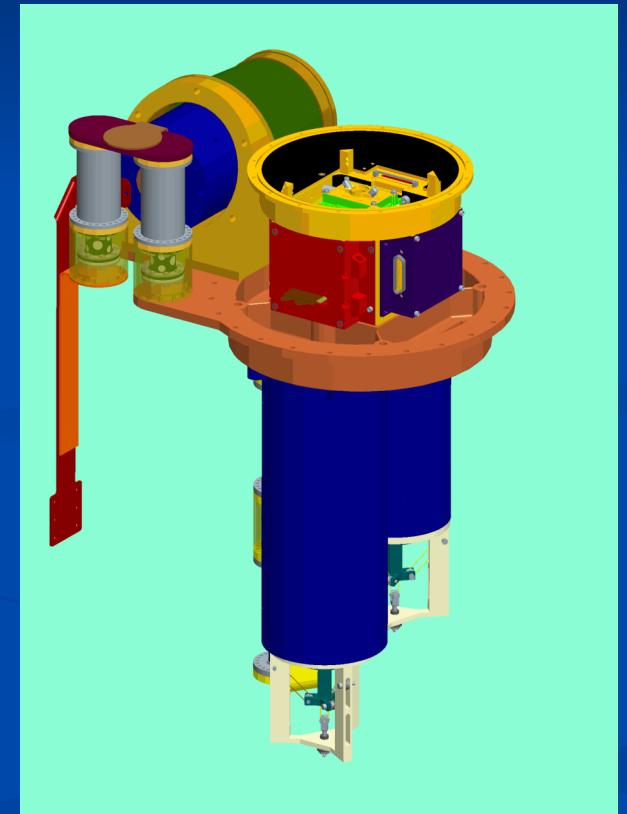
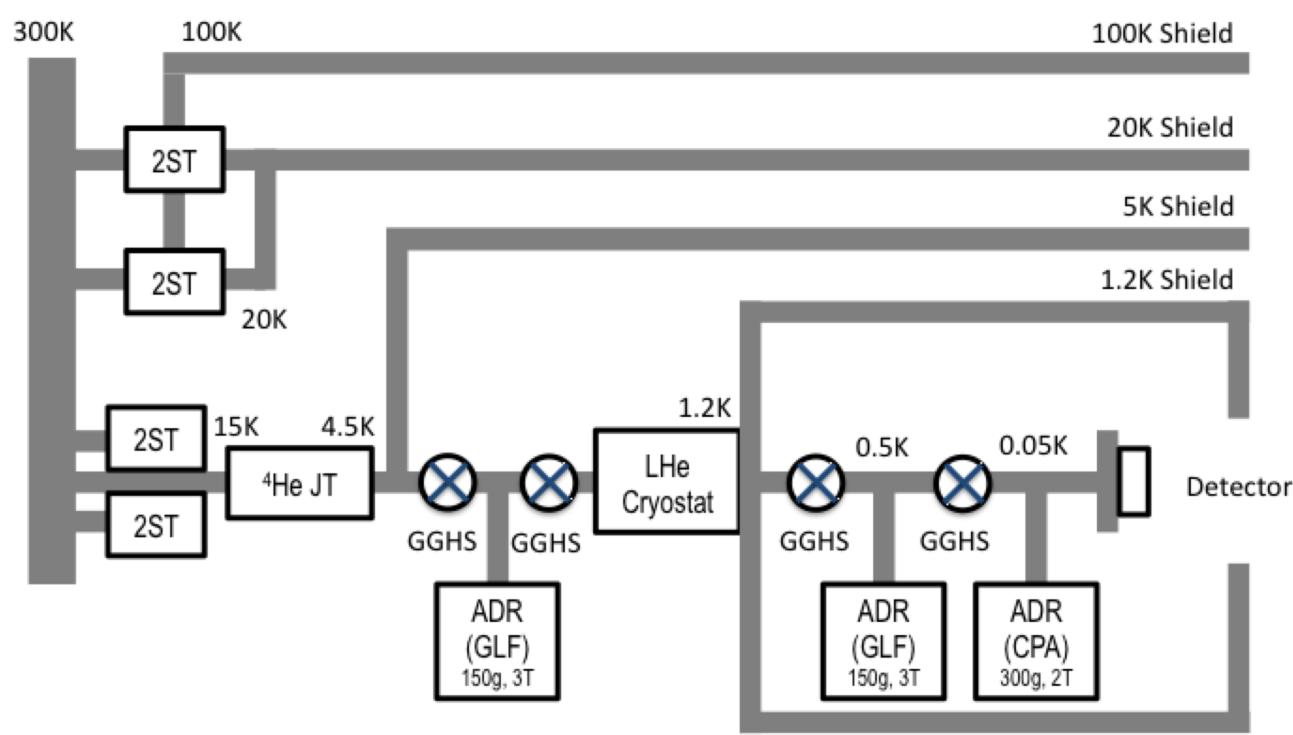
Soft X-ray Spectrometer(SXS)





Astro-H

Soft X-ray Spectrometer(SXS)

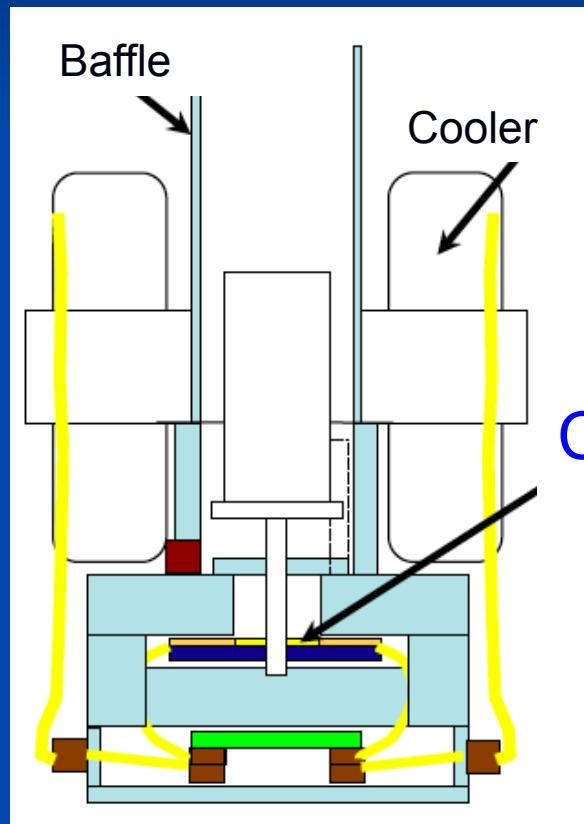


Three stage ADR

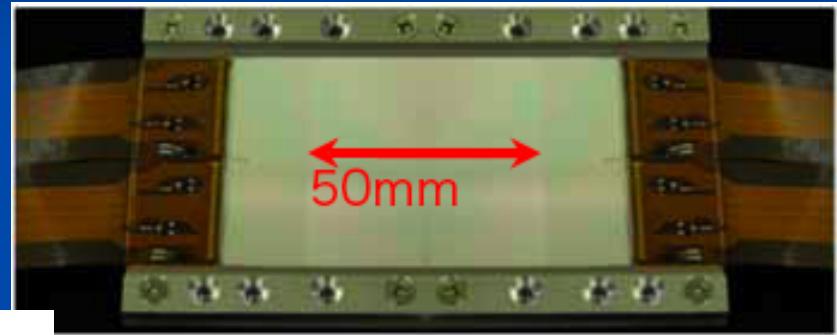


Astro-H

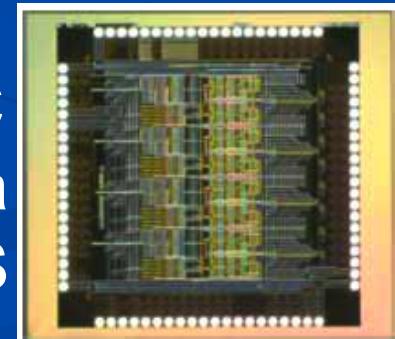
Soft X-ray Imaging Detector (SXI)



CCD by HPK
Osaka
Kyoto



ASIC
Osaka
ISAS



For IXO XGS CCD?



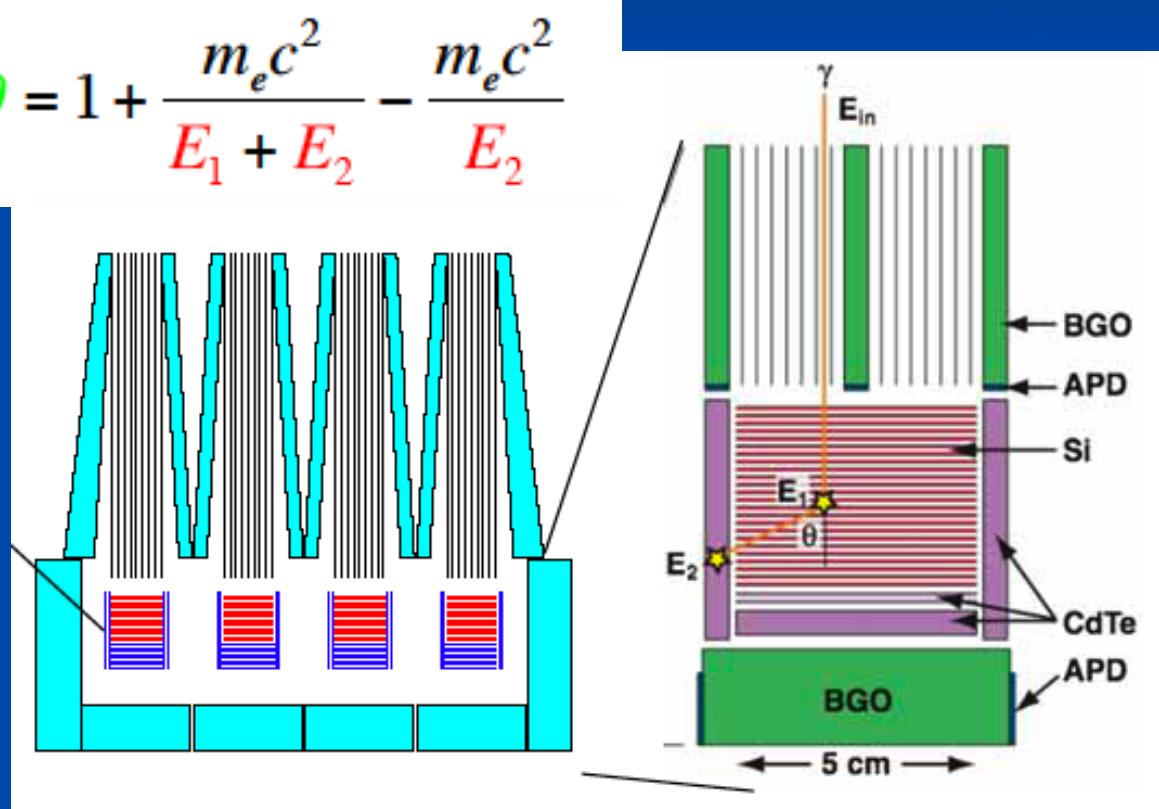
Astro-H

Soft γ -ray Detector(SGD)

Compton Kinematics

$$\cos \theta = 1 + \frac{m_e c^2}{E_1 + E_2} - \frac{m_e c^2}{E_2}$$

10 - 600 keV
 $dE \sim 2 \text{ keV}@40\text{keV}$



Possible areas of Japanese Contribution to IXO

Science Study

Science Meeting in Japan(June 2009 Otaru)

Mission Instruments

Extensible Optical Bench

X-ray telescopes

General/hard X-ray response

Cryogenic System

Focal Plane Instruments

Spectrometer(XMS), WFI, XGS(CCD)

Hard X-ray Imaging detector(part of WFI)

Operation

Receiving station

Science Meeting in Japan

July 3, 2009 at Otaru, Japan

July 3 (Friday)

Session I

Mission description I Philippe Gondoin (ESA)

Mission description II Nicholas White(NASA)

Reports from TWG

Glass mirror optics Rob Petre

Si pore optics Philippe Gondoin (ESA)

HXT Hideyo Kunieda

Session II

Reports from IWG

WFI/HXI

XMS

Grating

Lother Strueder

Kazuhisa Mitsuda

John Nousek

Session III

AGN evolution K. Nandra

Stars and star formation M. Tsujimoto

SNR science S. Yamauchi

Session IV

Supermassive black holes K. Iwasawa

Compact objects T. Dotani

Polarimetry: a new window to the X-ray Universe

G. Matt

Neutron star equation of state D. Barret

Session V

Cluster evolution and cluster cosmology H. Boehringer

The Galactic center and galactic outflows

T. Tsuru

J. Kaastra

WHIM study

Concluding remarks

H. Kunieda, N. White, A. Parmar

Suzaku Conference 30/6-2/7

“The Energetic Cosmos :
from Suzaku to ASTRO-H”

Possible areas of Japanese Contribution to IXO

Science Study

Science Meeting in Japan(June 2009 Otaru)

Mission Instruments

Extensible Optical Bench

200-250KEuro

X-ray telescopes

General/hard X-ray response

Cryogenic System

Focal Plane Instruments

Spectrometer(XMS), WFI, XGS(CCD)

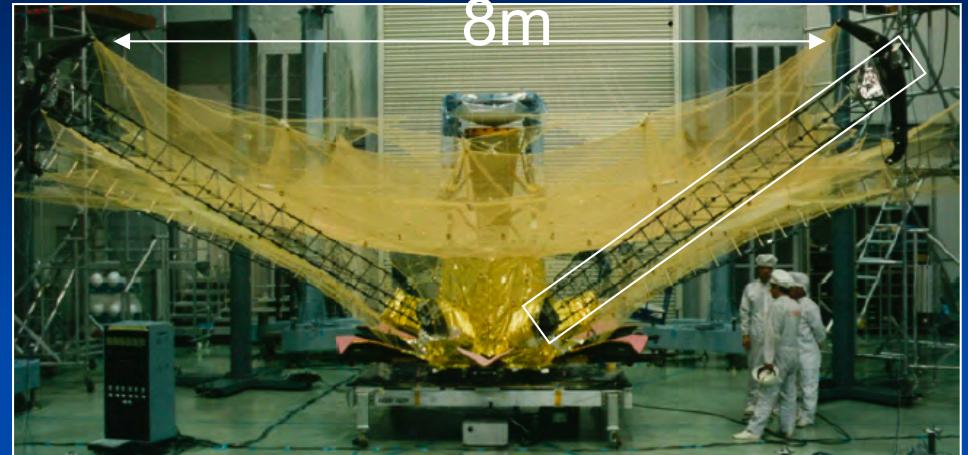
Hard X-ray Imaging detector(part of WFI)

Operation

Receiving station

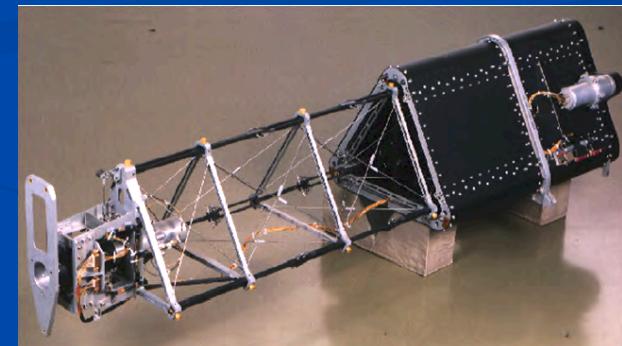
Extensible Optical Bench (EOB)

Heritage of HALCA
8 m radio antena



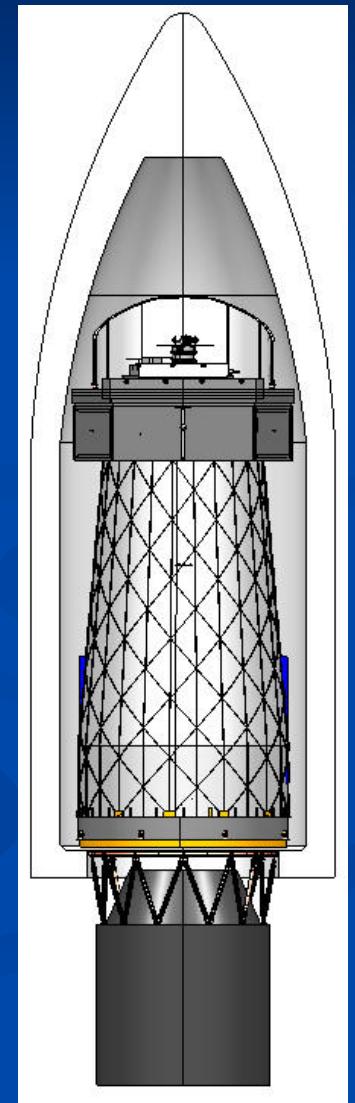
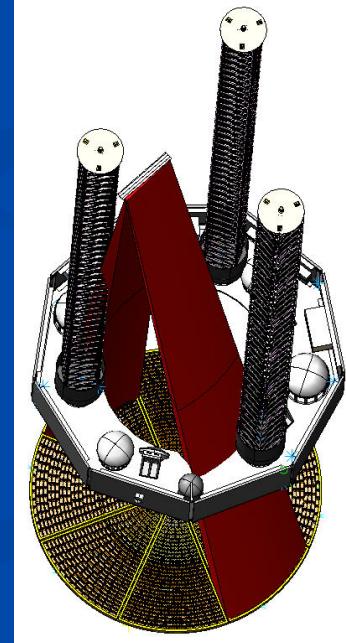
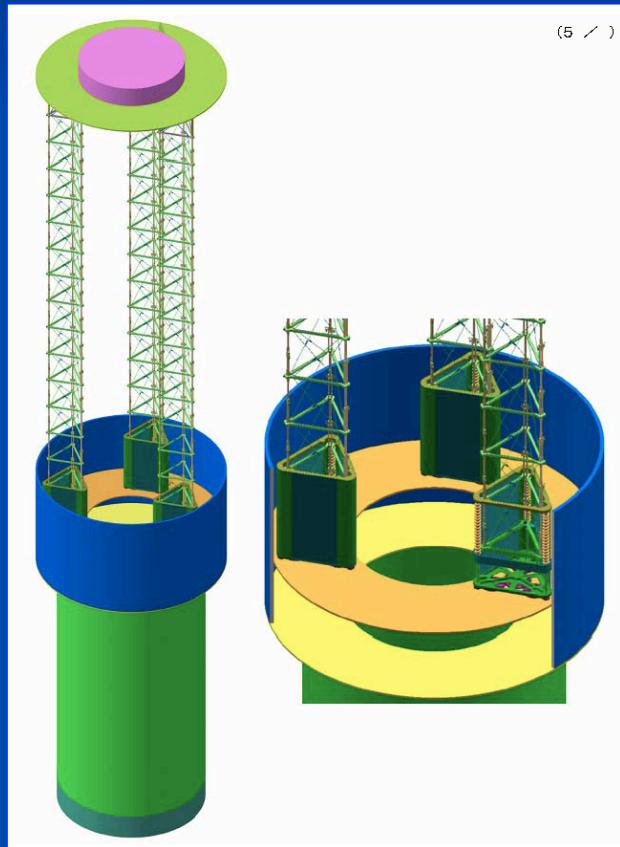
Triangular unit
25 cm --> **75 cm(IXO)**

Extension length
4m --> **12 m(IXO)**



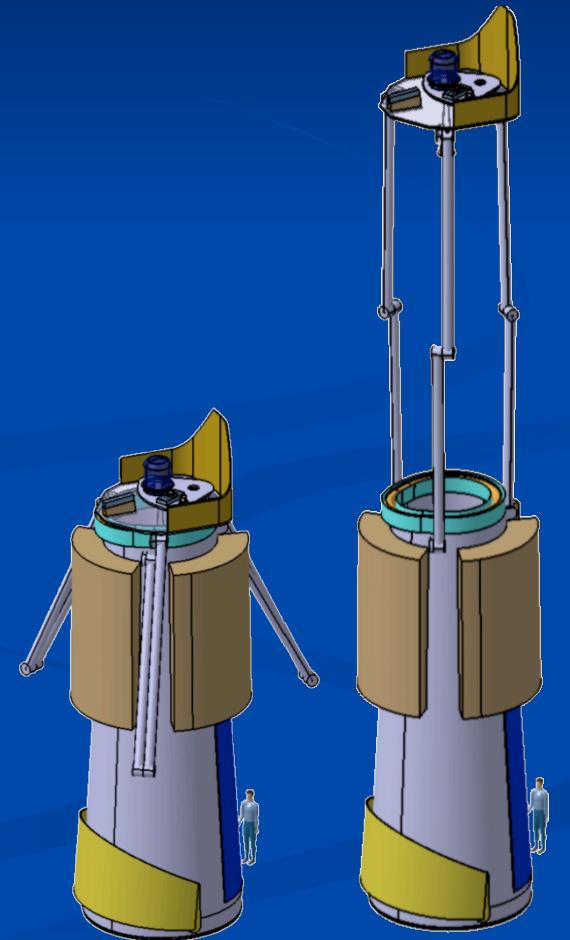
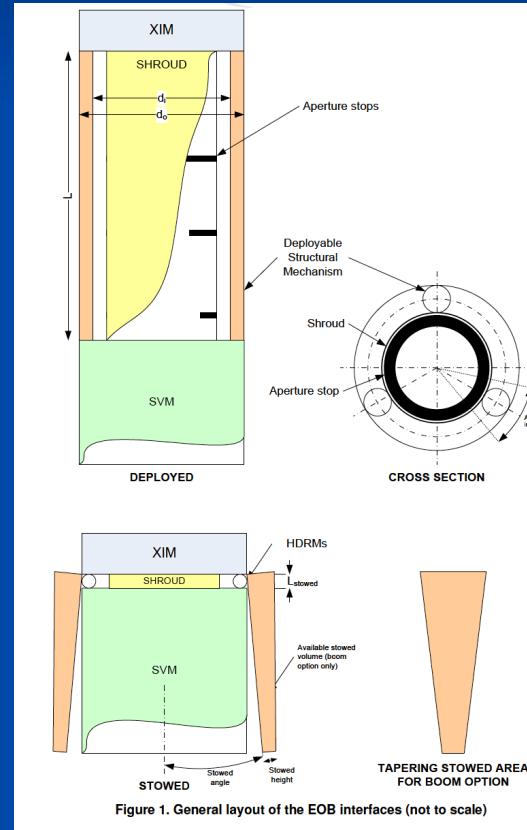
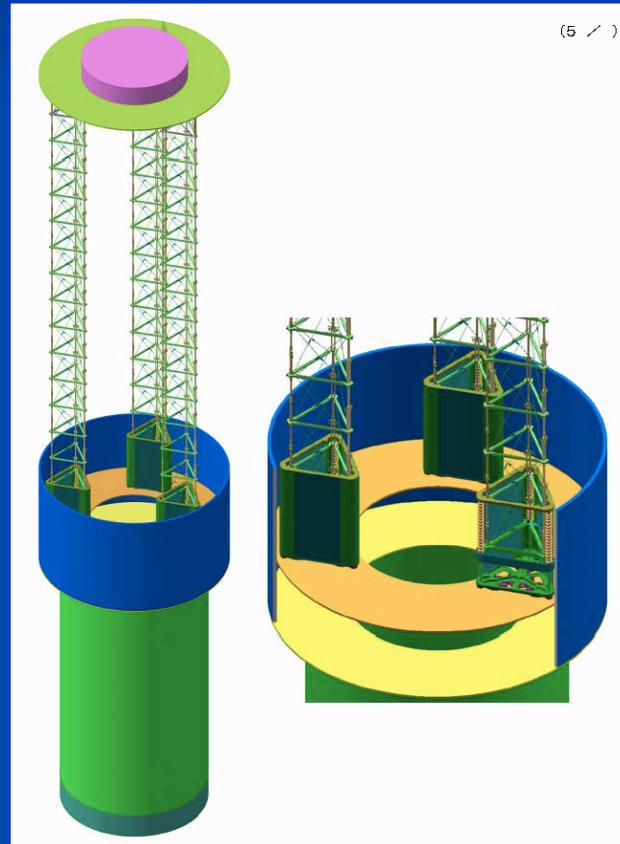
Extensible Optical Bench (EOB)

I/F to the NASA version of Model Spacecraft



Extensible Optical Bench (EOB)

I/F to ESA version Model Spacecraft (TBD)



Nippl Co.

Extensible Optical Bench (EOB)

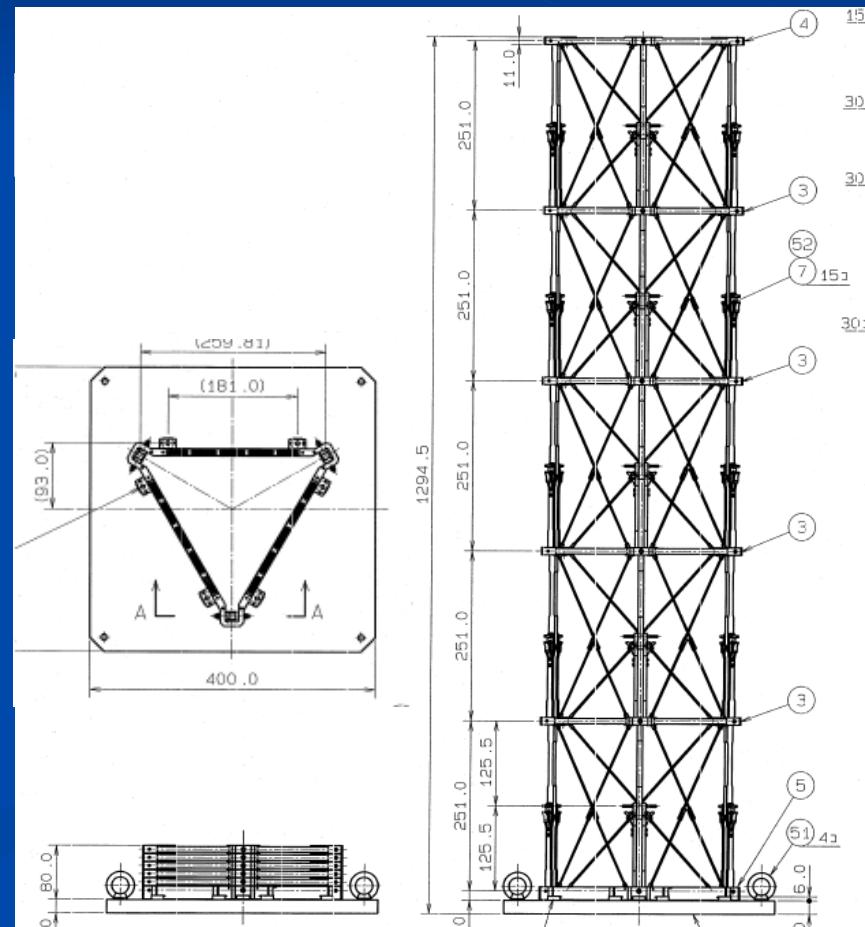
2009

Design and production
of EOB elements

2010

Assembly
Mechanical and
thermal tests

Engineering Model of EOB



Nippi

Possible areas of Japanese Contribution to IXO

Science Study

Science Meeting in Japan(June 2009 Otaru)

Mission Instruments

Extensible Optical Bench

X-ray telescopes

General/hard X-ray response

Cryogenic System

Focal Plane Instruments

Spectrometer(XMS), WFI, XGS(CCD)

Hard X-ray Imaging detector(part of WFI)

Operation

Receiving station

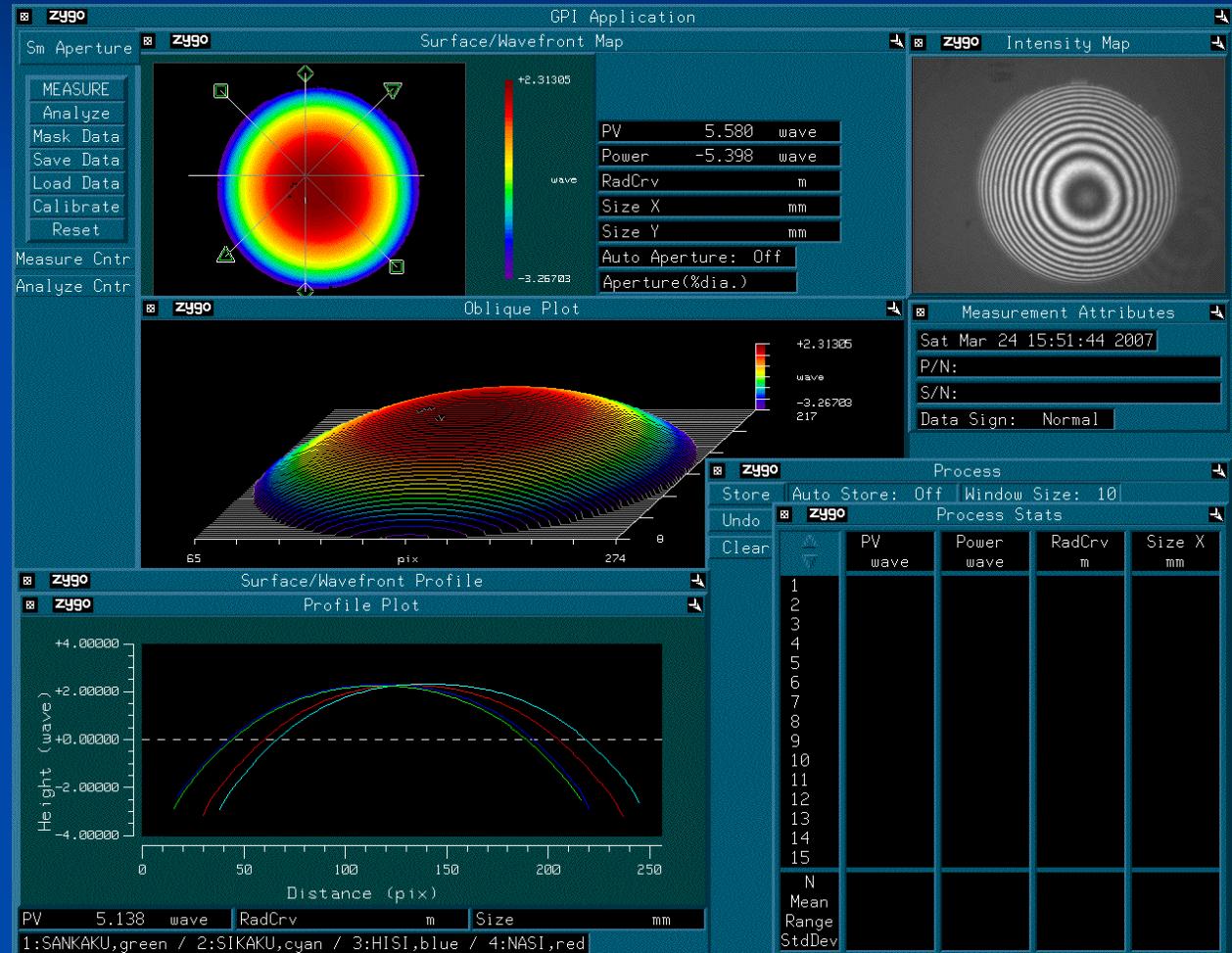
X-ray telescopes

Stress of coatings on thin substrates

0.5t Fused silica
W/C multilayer
~ 1 Gpa

Pt/C multilayer
~ 0.5 GPa

d=4nm
N=30
 $\Gamma=0.4$



X-ray telescopes

Stress of coatings on thin substrate

W mono layer

3 - 4 GPa

C mono layer

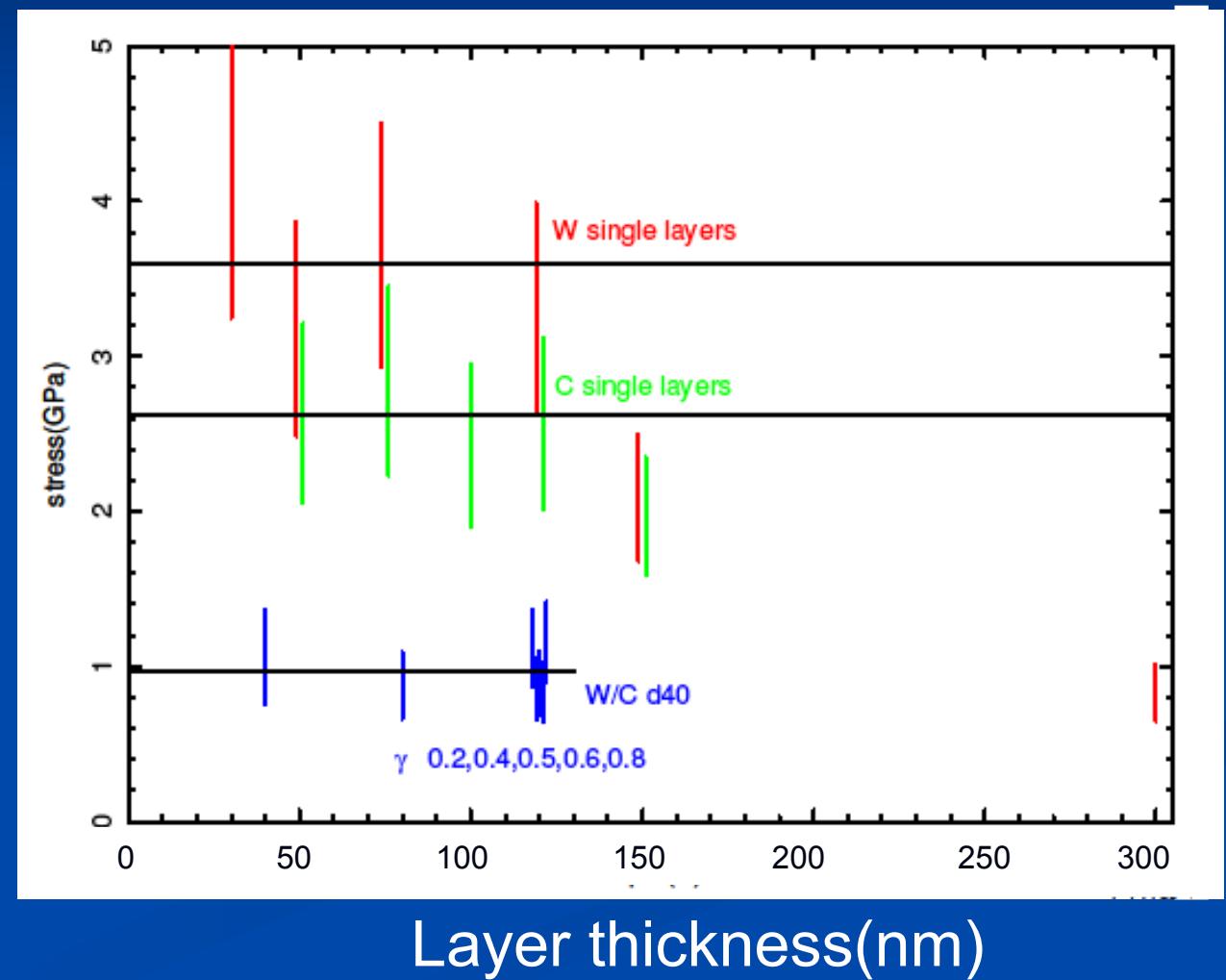
2 - 3 Gpa

W/C multilayer

~ 1 Gpa

$d = 4\text{nm}$

$N = 10 - 30$ pairs



X-ray telescopes

Stress of coatings on thin substrate

$d = 120 \text{ nm}$ $N=1$

(W: 48 nm, C: 72 nm)

$d = 60 \text{ nm}$ $N=2$

(W: 24 nm, C: 36 nm)

$d = 4 \text{ nm}$ $N=30$

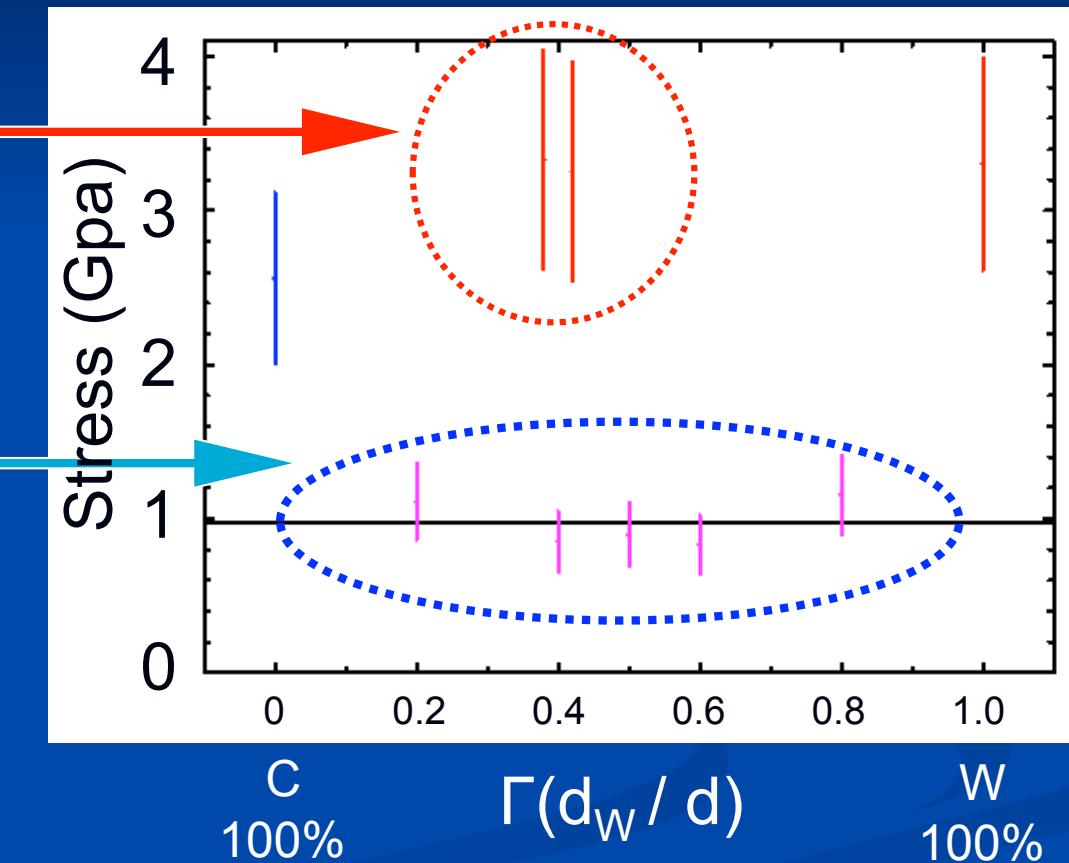
$\Gamma=0.2$ (W: 0.8 nm, C: 3.2 nm)

$\Gamma=0.4$ (W: 1.6 nm, C: 2.4 nm)

$\Gamma=0.5$ (W: 2.0 nm, C: 2.0 nm)

$\Gamma=0.6$ (W: 2.4 nm, C: 1.6 nm)

$\Gamma=0.8$ (W: 3.2 nm, C: 0.8 nm)



Critical thickness for strong stress to work

X-ray telescopes

Scattering Tail of (ML) Super mirror

$$R = R_0 \exp \{-(4\pi\sigma \cos\phi/\lambda)^2\}$$

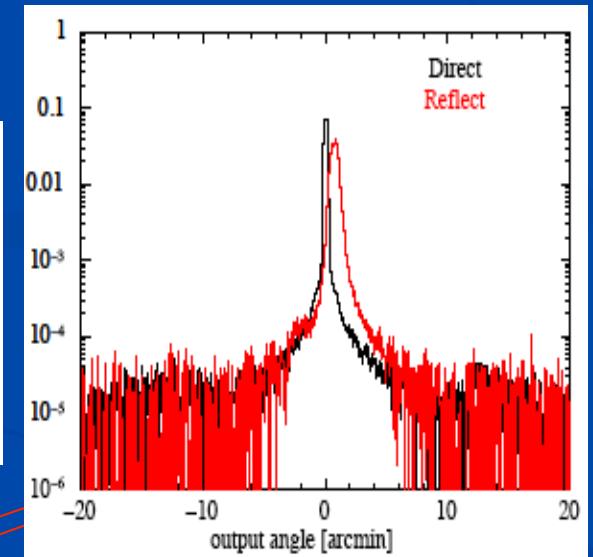
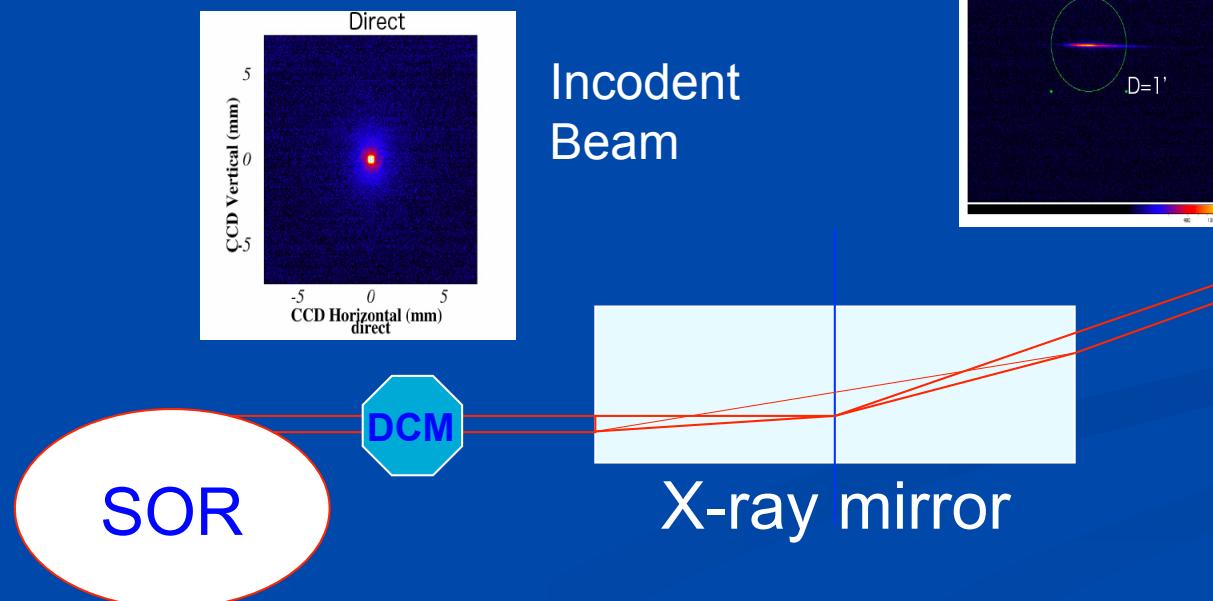
Broadening of image blur?

Serious at high energies

$\lambda = 0.04 \text{ nm} : 30 \text{ keV}$

$\cos\phi = \sin\theta \sim 1/300 (@0.2^\circ)$

$\sigma \leq 0.3 \text{ nm}$



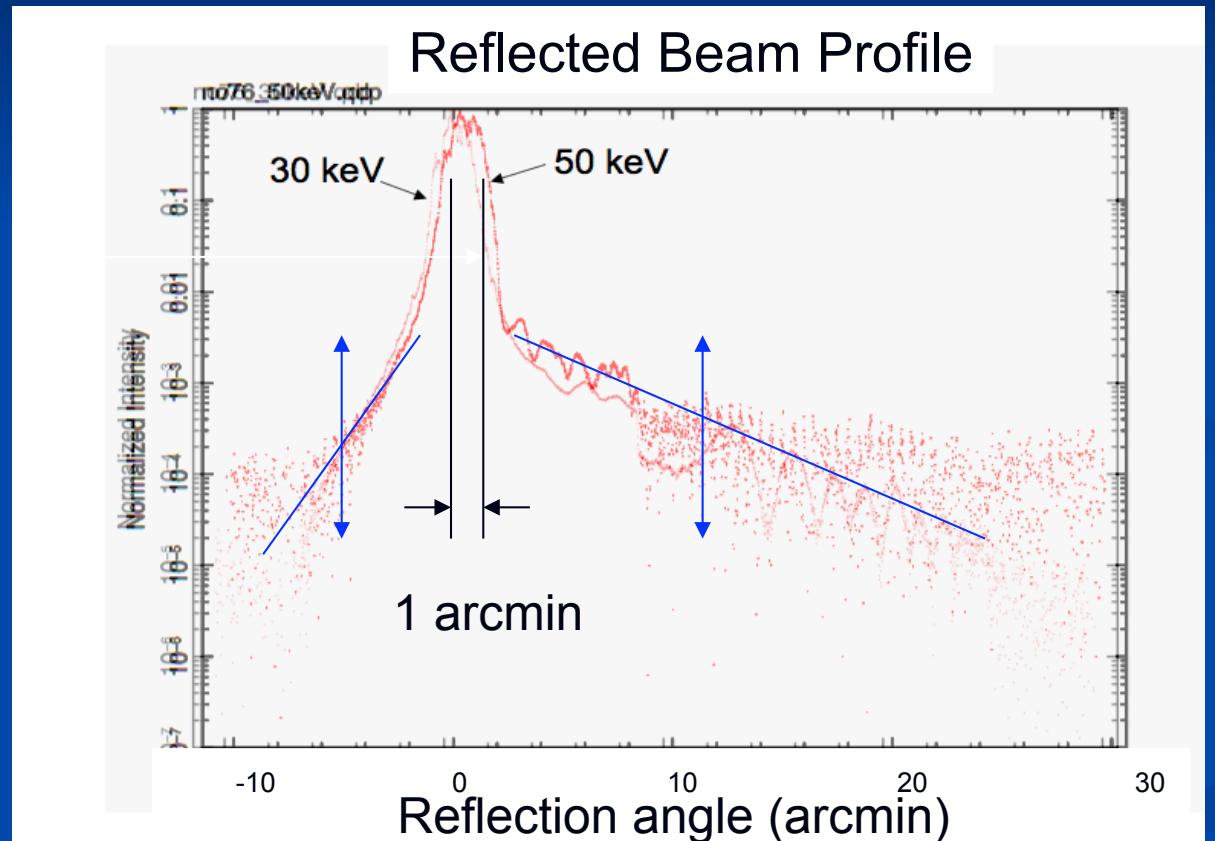
X-ray telescopes

Scattering Tail of ML Super mirror

Tail level is equal for 30 and 50 keV.

Ripples are seen at Bragg angles.

Arcsec level blur has to be confirmed but scattering does not degrade hard X-ray image as bad as 30" if surface roughness is less than 0.3 nm rms



Possible areas of Japanese Contribution to IXO

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Mission Instruments

Extensible Optical Bench

X-ray telescopes

General/hard X-ray response

Cryogenic System

Focal Plane Instruments

Spectrometer(XMS), WFI, XGS(CCD)

Hard X-ray Imaging detector(part of WFI)

Operation

Receiving station

Cryogenics & X-ray Microcalorimeter Spectrometer(XMS)

International Consortium

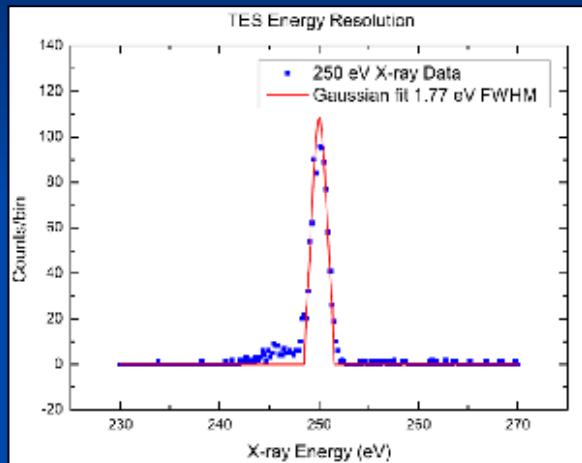
SRON(Netherlands)

NASA/GSFC, NIST(USA)

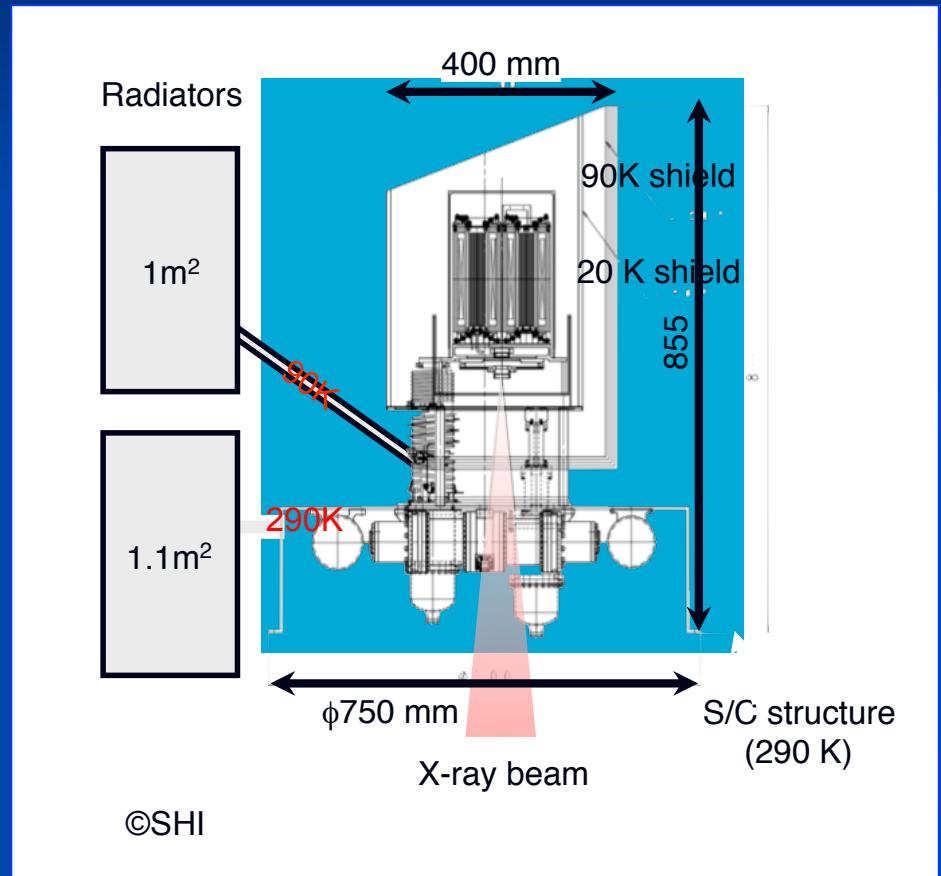
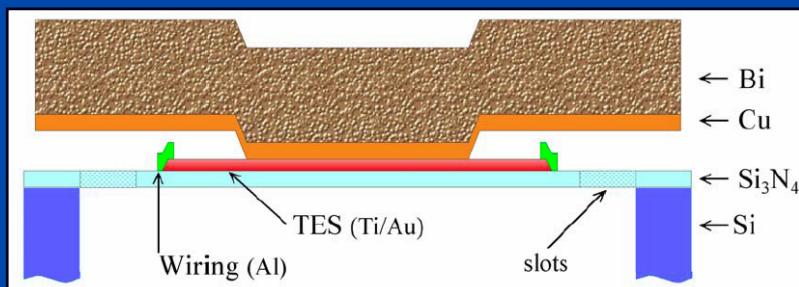
Air Liquide, CNRS(France)

ISAS, Metroplitan U. Kanazawa U.(Japan)

X-ray Microcalorimeter Spectrometer(XMS)



$dE < 3 \text{ eV}$
at 50 mK



Cryogenics & X-ray Microcalorimeter Spectrometer (XMS)

Electronics for TES microcalorimeter
Frequency-Domain-Multiplex

Design of TES microcalorimeter array

Design of full cooling chain

50 mK dADR and drive electronics

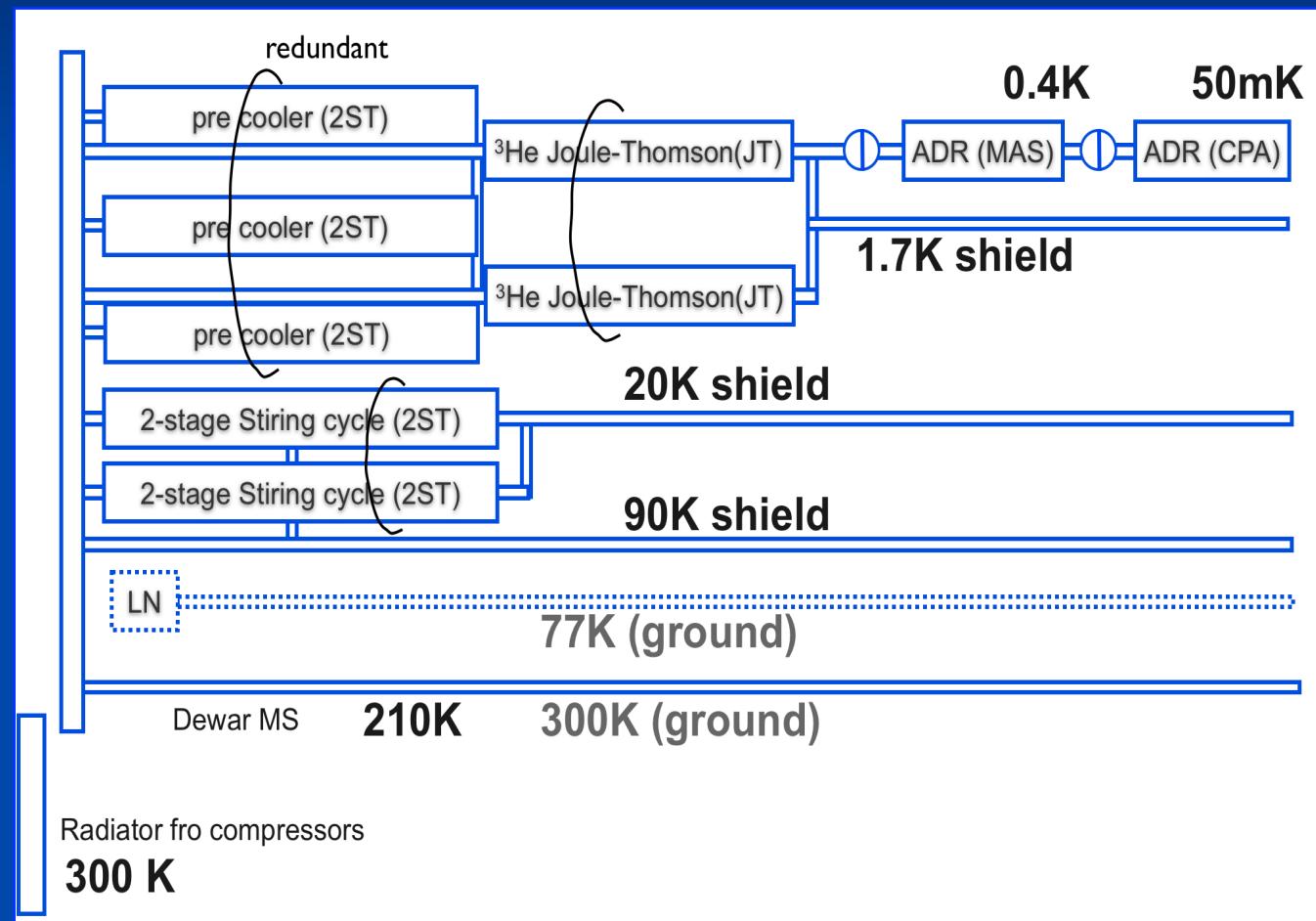
Long-lifetime 1 K cooler

Compressor for closed cycle dilution cooler

Digital Data processing

Cryogenics

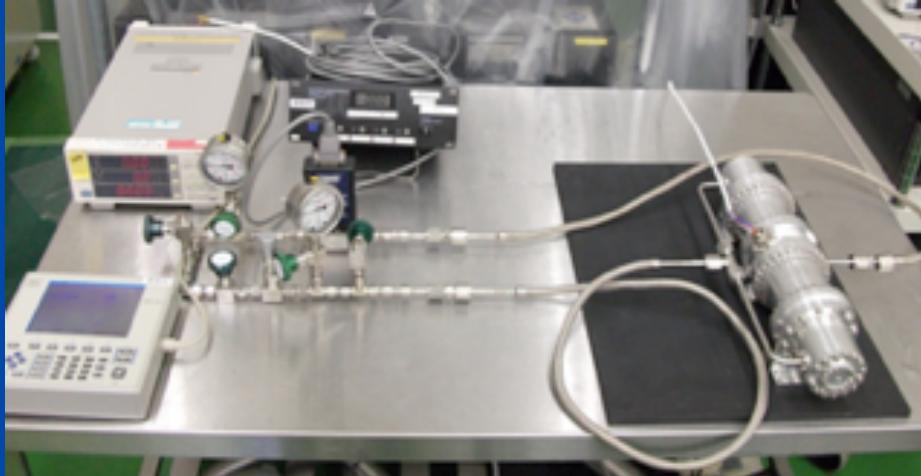
Design of full cooling chain



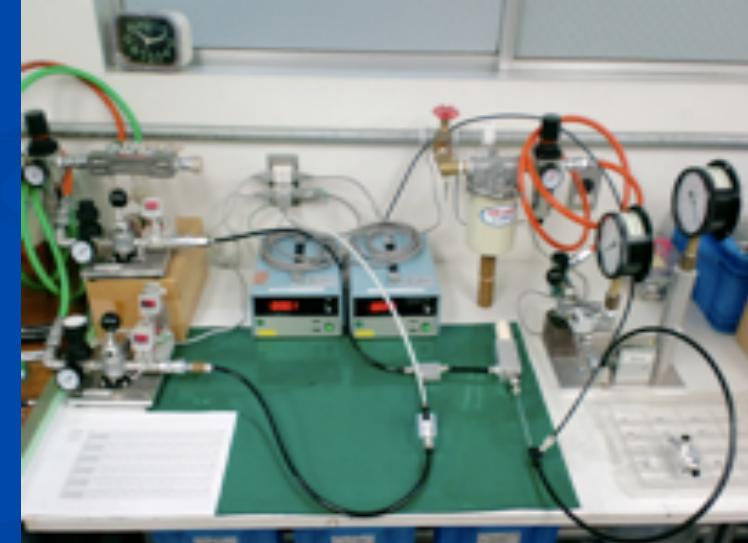
Cryogenics

Compressor for closed cycle dilution cooler

2 stage cooler for
 ^3He JT cooler



Test set-up of
Ejector pump



CV-1 0HS, CV-20HS

Possible areas of Japanese Contribution to IXO

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Science Meeting in Japan(June 2009 Otaru)

Mission Instruments

Extensible Optical Bench

X-ray telescopes

General/hard X-ray response

Cryogenic System

Focal Plane Instruments

Spectrometer(XMS), **WFI**, XGS(CCD)

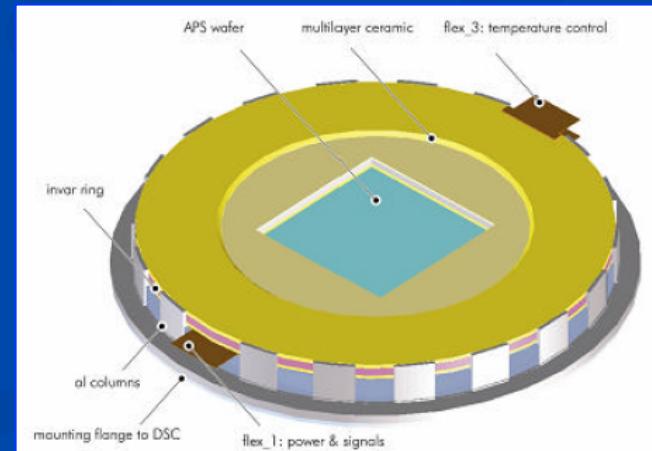
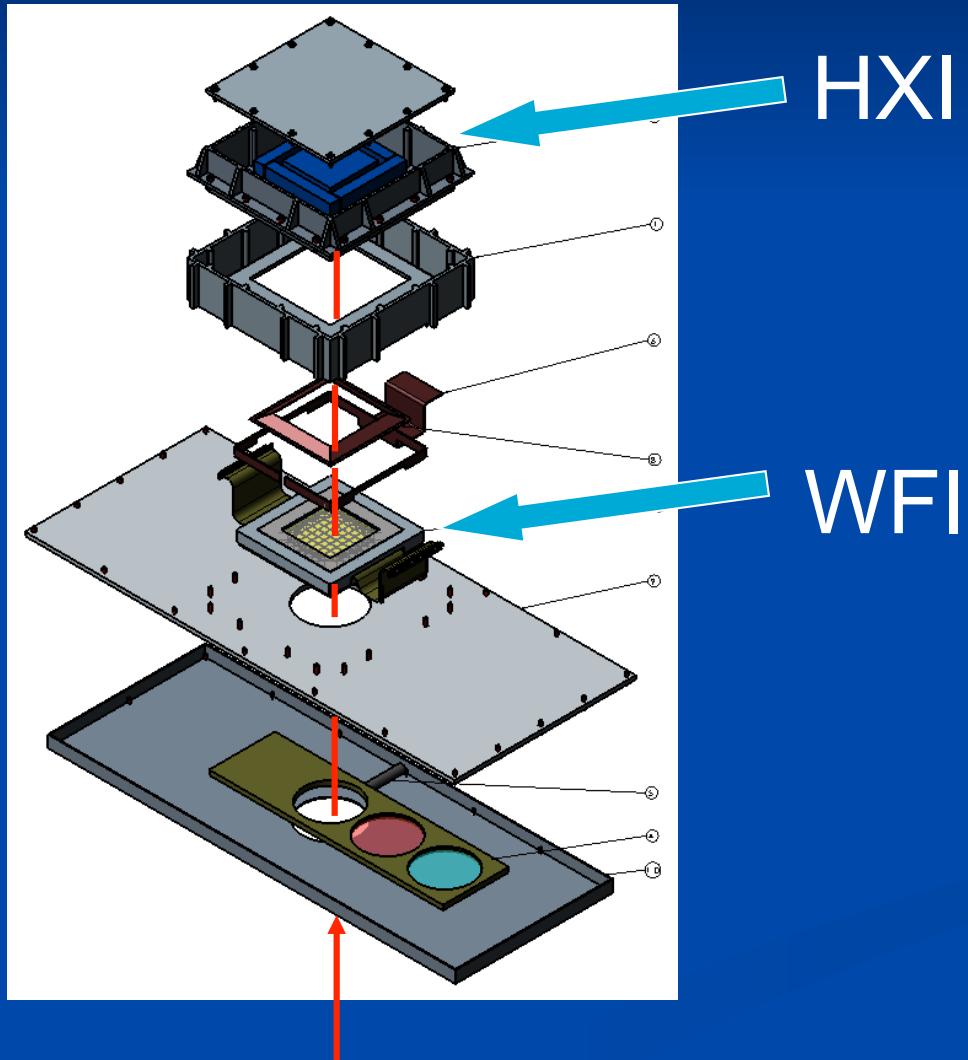
Hard X-ray Imaging detector(part of WFI)

Operation

Receiving station

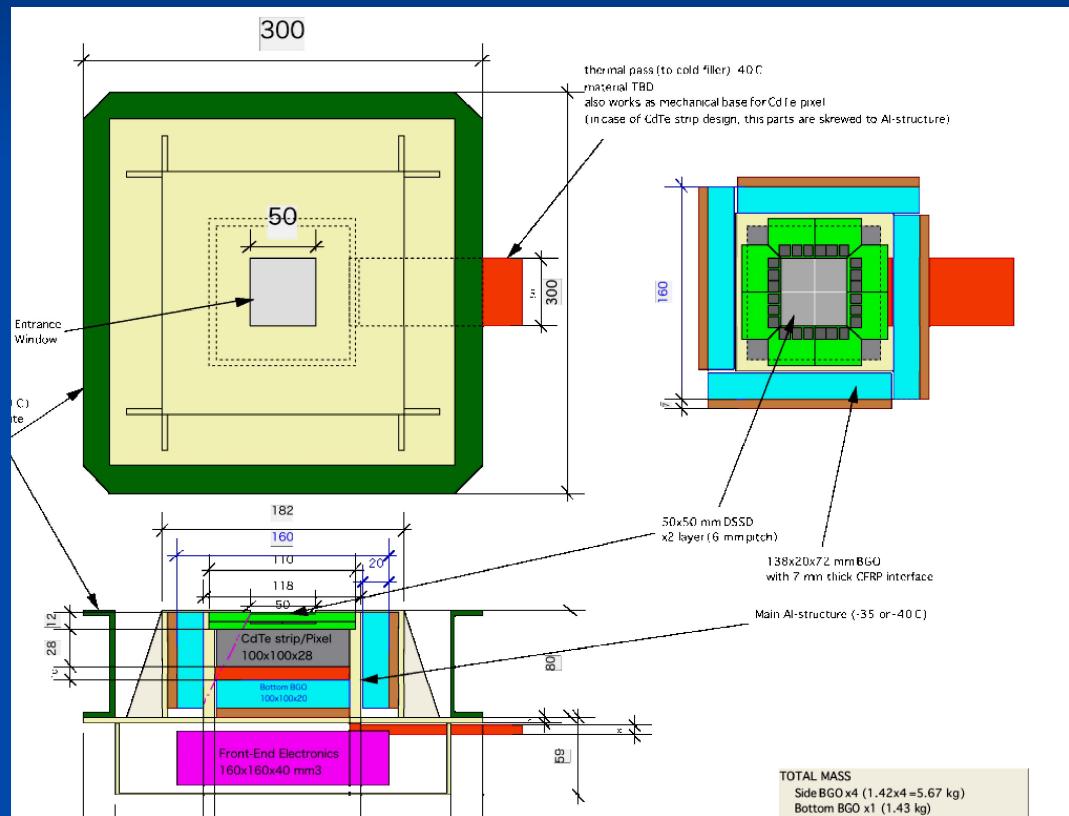
Wide Field Imager(WFI)

Hybrid design of WFI



WFI(Hard X-ray Imager part)

Configuration of HXI



2 layers 50 x 50 mm DSSD
(0.6mm pitch)

CdTe pixel detector
(-35-40°C)

138x20x72 BGO
5 sides shield

Organization for IXO in Japan

SCG: Kunieda(co-chair), Takahashi, Dotani, Tsuru
Mitsuda, Ohashi, Kokubun

SST: Ohashi(co-chair), Ueda, Kitamoto,
Matsushita, Terashima, Yamasaki,

TWG: Kunieda(co-chair), Awaki, Ishida, Maeda

IWG: Tsunemi(co-chair), Takahashi, Mitsuda,
Hayashida, Nakazawa, Fujimoto

Proposal to ISAS committee

2010 April-May Preparation of the proposal
End of June **MDR** proposal submission
Sep.-Oct. Conclusion
-->ESA CV in Dec. for Definition Study process

Medium size (< 200M Euro)X-ray mission after Astro-H

Possible area of Japanese contribution
Hard X-ray Imaging System
(Telescope, EOB, Imaging detector)
High resolution spectrometer
(Cryogenic system, detector)
CCD, SSD
Operation(Station)

Possible areas of Japanese Contribution to IXO

Science Study

Science Meeting in Japan(June 2009 Otaru)

Mission Instruments

Extensible Optical Bench

X-ray telescopes

General/hard X-ray response

Cryogenic System

Focal Plane Instruments

Spectrometer(XMS), WFI, XGS(CCD)

Hard X-ray Imaging detector(part of WFI)

Operation

Receiving station

Update on JAXA studies and way forward in Japan

**Hideyo Kunieda
Nagoya University
and
IXO Working Group**

IXO Science Meeting @Paris, April 27-29, 2010